

The Virtual Collaboration Environment: New Media for Crisis Response

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ABSTRACT

This paper concerns the use of new media technologies, including virtual worlds and web 2.0, for on-line collaborative activities, and specifically for the provision of expert advice about the response to large-scale crises. Internet technologies in general offer rich possibilities for interactions involving remote experts; however, the diversity, novelty and power of these technologies are such that to introduce them into problem-solving episodes without first developing a model of the nature of those episodes and the type of collaborative support they require, risks confusing and discouraging users. After a brief discussion of the nature of distributed collaboration and the implications this has for any technical support, we describe a virtual collaboration environment that has been developed to foster task-focused communities and support them through specific problem-solving episodes, and present some of the results of evaluation experiments.

Keywords

virtual collaboration, intelligent task support, web 2.0, social media, virtual worlds, cognitive work analysis.

INTRODUCTION

Large-scale crisis response situations require collaboration among individuals belonging to different organizations and having different backgrounds, training, procedures and objectives. Communication networks offer the possibility to call upon expertise from around the planet to assist during emergencies; however, coordinating the activities of geographically dispersed experts to form a coherent response raises a number of questions about the most effective use of communication technologies, especially where these are novel and have not been designed for such activities. Without a more considered use of technology, opportunities for leveraging expertise and resources across organizations can be haphazard, and the response to the crisis can appear as chaotic as the crisis itself.

Seeking more effective and efficient means to facilitate crisis response, in 2009 the US Joint Forces Command (USJFCOM) and the US Army Research Laboratory's Human Research and Engineering Directorate (ARL HRED) launched a project under the direction of Jeffrey Hansberger to design and evaluate a *Virtual Collaboration Environment* (VCE) and to demonstrate its potential for distributed crisis response planning. Involved in this project are groups from the University of Edinburgh, the University of Virginia, Carnegie Mellon University and Perigean Technologies LLC, each of which had an existing and complementary interest in collaborative work.

The initial technical concept behind the VCE was to investigate the potential of new media technologies, specifically social networking and virtual worlds, to provide a virtual environment that fosters community spirit and collaborative effort in some particular field (a field in which, we assume, there exists a potential community of users who have complementary knowledge or skills that contribute to problem-solving; note that this environment is not restricted to crisis response tasks). Thus envisaged, the VCE would have several specific requirements:

- The creation and maintenance of a community of on-line users with diverse backgrounds (including those with

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little or no prior experience of virtual or on-line communities). In the first instance, the VCE is intended to support a Whole of Society Crisis Response (WoSCR) community, a loosely affiliated community of subject-matter experts and crisis responders drawn from international government and civilian organizations for the purpose of contributing their specialized knowledge to crisis response planning activities. In the course of the project an initial mailing list of 1600 people already involved in such activities was used to establish the community, of which, at the time of writing, some 300 are active within the VCE facilities that have been provided. It contains members from a number of countries (although initially with a strong US bias) drawn from the worlds of government, business and academia.

- The provision for the users of mechanisms for the creation and long-term development of an on-line and on-going body of experience, knowledge and debate about the field in question.
- The ability for users to act collaboratively to formulate agreed solutions during specific problem-solving episodes.

The experiments that were conducted to evaluate the VCE focus on the last of these requirements, since the success of the VCE as a community-building tool can only be evaluated in the long run. For the experiments, the VCE was used in responsive mode, with users asked to collaboratively create emergency response plans. The ultimate aim here was to show that the use of the VCE leads experts “to better produce better solutions”. In other words, we are interested in two aspects, namely that both the quality of the solution plan and the quality of the planning process be improved. Of course, and especially in experiments, determining that one proposed solution is better than another is difficult; we can however look to more objective contents of the plans such as the aspects that they cover. Similarly, when comparing the quality of two processes we must look to other measures to try to assess the efficiency of the planning and the contributions of participants.

Technologies for Collaboration

The typology commonly used to differentiate technologies within the Computer-Supported Cooperative Work (CSCW) community categorizes them according to “their abilities to bridge time and to bridge space” (Baecker et al., 1995). Collaborations can occur either with participants physically collocated or else at remote locations. Here we are exclusively interested in remote collaborations. Similarly, all participants may collaborate at the same time, or the participants may work in their own time. The former requires some mode of “synchronous communication”, the latter “asynchronous communication”. In this case, collaborations in the VCE would have two, quite different, aspects: a continuous asynchronous collaboration among users to discuss and develop on-line documentation pertaining to their field of interest (activities which would also help foster a sense of community); and interspersed synchronous problem-solving collaborations of relatively short duration in which their expertise is put into practice.

These considerations would influence the precise nature of the VCE; more concretely, they were embodied in the decision to use some combination of web 2.0 and virtual worlds technologies. The term “web 2.0” denotes an approach to generating web content that is always open to the possibility of – and explicitly encourages – the contribution and collaboration of others. As such, a web 2.0 web page might be distinguished from a conventional web page by its content being (more or less explicitly) the result of the interplay of the activities of multiple authors or agents, by its openness and by the explicit mechanisms it provides for contributing content. Indeed, one might go further and suggest that much of the appeal of social networking sites, blogs, wikis and so on lies in the means they give us to assert our own presence as member of some community and to have it later affirmed by the interaction (by the commenting, supplementing, contradicting, erasing) of others in an on-going editing process. In other words, web 2.0 encourages and rewards collaboration, and as such represents an exciting development for those interested in exploiting the potential of joint activity.

However one limitation (from the perspective of the VCE) of the web 2.0 world is its general assumption that contributions occur in a more or less temporally linear sequence: one post follows and responds to another. Here, however, we require some mechanism for the simultaneous presence (and hence simultaneous collaboration) of individuals. For certain types of interactions and collaborations – those that require timely and agreed decisions, or the validation or authority conferred by the presence of certain individuals – shared presence still remains a necessity. While this sort of interaction might be provided by teleconferencing or internet messaging/telephony tools such as Skype, in this paper we present the idea that virtual world spaces can better fulfil this role. Specifically, we argue that virtual spaces can enhance the same-time/different-place interaction of existing tele- and video-conferencing tools by providing synchronous virtual meeting support within a space that acts as a persistent repository of informational objects representing resources used and generated by the collaboration, and moreover

can do so in such a way as to complement the rich potential of web 2.0 technologies as means for asynchronous collaboration. The general term we use for this virtual meeting space is an *I-Room*.

Hence, it was envisaged that web 2.0 and virtual worlds technologies together would provide the technical backbone for meeting these requirements. As a first step, in order to validate these initial assumptions, a *Cognitive Work Analysis* (CWA) was performed; this is described in the following section. We then go on to describe the varied technologies that comprise this environment, and discuss an empirical evaluation of its use during a realistic crisis response task.

RELATED WORK

The idea of building virtual teams and communities for emergency response has been explored in a number of projects. Recently, within the ISCRAM community, (Yao *et al.*, 2010) have built a system that allows virtual teams of geographically distributed experts to create and discuss emergency scenarios. Collabbit (de Lanerolle *et al.*, 2010) is a virtual dashboard that facilitates distributed asynchronous information sharing in emergency situations. However, we have not found work that aims to support a virtual collaboration environment with a specific protocol and tools to enact it. Perhaps more interesting is the work of (Díez *et al.*, 2010) which describes a number of design criteria aimed at supporting virtual communities of practice, several of which are implemented in the system described here.

COGNITIVE WORK ANALYSIS OF DISTRIBUTED COLLABORATION

The design of the VCE was guided by a Cognitive Work Analysis (Vicente, 1999; Lintern, 2009) of distributed collaboration, with the goal-directed phases of *forming, storming, norming and performing* (Tuckman, 1965) providing a framework for understanding and supporting specific instances of collaborative tasks.

Any group of humans brought together to perform some task can be considered to constitute a cognitive system: it has knowledge and understanding, can plan, decide, learn, and in general solve problems. However, this system invariably functions within a technological context: people use technical artifacts to perform their tasks (even natural language is such an artifact, properly speaking), and, moreover, apply particular, perhaps socially or culturally mediated, physical and mental techniques in their use of these artifacts. A CWA attempts to make explicit the constraints that hold on work – rather than the task, hence maintaining the focus on the human – that is done within complex cognitive systems (in short, those that have a certain amount of unpredictability and so cannot be proceduralized). It is also normative, in the sense that it is intended to identify the technical and organizational relationships that must be in place for the work to be performed effectively. In this manner, a CWA typically focuses on how work can be done compared to other types of task analyses that focus on how work should be done in a limited set of situations, which can decrease the flexibility and adaptability of the socio-technical system. While not itself a design method, the results of a CWA can be used to support particular design decisions, as was the case here.

A CWA progresses through multiple phases that systematically analyze the constraints on work, agents, organizations and activities. Here we restrict ourselves to discussing the results of the first – and probably the most difficult and important – phase: *Work Domain Analysis*.

This first phase of the CWA involves identifying the activity-independent constraints of the work domain; following (Lintern, 2009), here this has been done by decomposing the domain according to five levels of abstraction arranged hierarchically. This analysis results in the map shown in Figure 1, with content as follows:

- Domain purpose: the overarching goal to be achieved – in this case, *distributed collaboration*.
- Domain values and priorities: principles or qualities on which work in the domain is founded – in this case, we identify *coordination, communication* and *activity awareness* as essential components of distributed collaboration.
- Domain functions: the realization of the domain values and priorities (and fulfillment of the domain purpose) as abstract functions within the domain; in this case, we refer to the 4 stages of Tuckman's goal-directed group behaviour.
- Physical functions: the realization of the domain functions in terms of techniques (Pinelle, Gutwin and Greenberg, 2003).

- Physical objects: technological artifacts that provide some aspect of the identified physical functionality, with particular reference to the opportunities offered by web 2.0 technologies as well as existing technologies. Since we are trying to anticipate a collaborative environment that does not yet exist, or only partially, this level of the analysis is unavoidably biased by our interests and awareness of current technologies. The central position of the virtual 3D meeting space as a potential for supporting multiple physical functions lends a certain amount of credence to this as a potential tool for distributed collaboration; however, this can only be borne out by its successful use. It can be seen that the virtual space potentially offers all but one of the physical techniques that are provided by the other principal ‘synchronistic’ interaction technology, video conferencing (the omission being the loss of physical-gesture communication). In addition, the virtual space offers the opportunity for (persistent) information access and transfer. On this basis, for the VCE, a virtual space was chosen instead of video-conferencing.

Overall, the resulting analysis provides a coherent way of ensuring there is a technical solution for each of the identified domain functions and their physical manifestations, while avoiding the gratuitous introduction of technologies that add little or no useful functionality.

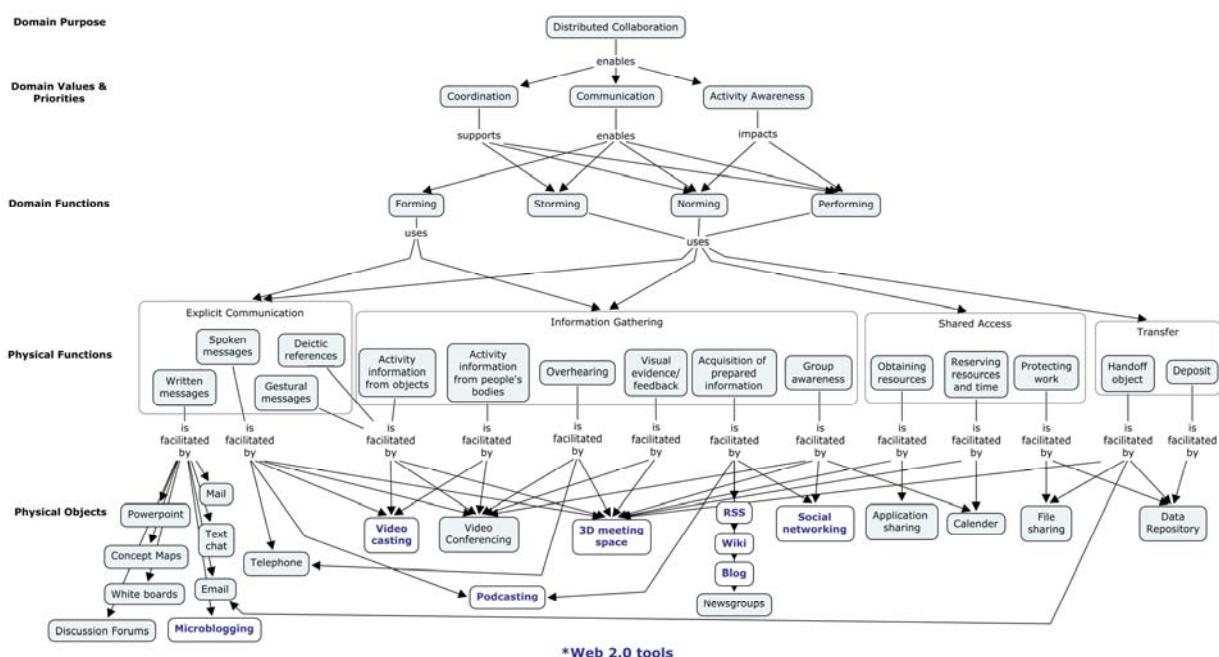


Figure 1. Cognitive Work Analysis Phase I – Work Domain Analysis.

OPENVCE: VIRTUAL COLLABORATION ENVIRONMENT PACKAGE

So with the results of the CWA going some way to confirm the initial assumptions, we could begin to put the technologies in place for the VCE. In this section we discuss three of these technologies, namely a web-based portal, a virtual collaboration space, and the collaboration protocols that were introduced to guide the use of the VCE. In their generic forms, these, along with other contributory technologies, have been packaged as the *OpenVCE* solution – *open*, since in the technologies chosen there was a strong bias towards those that are open source or open access, ensuring that the system as a whole would be available to as wide a range of potential user communities as possible.

Community Web Portal

The VCE includes a web-based portal that would provide the platform for the diachronic aspects of collaboration and communication, and for creating and sharing resources, as well as more general group-building activity and event awareness (<http://openvce.net> – see Figure 2). After some experimentation and discussion (see <http://openvce.net/forum-alternative-platforms> and <http://openvce.net/more>), the open-source Drupal®-based

software system was adopted as the platform for this site. Drupal is a widely used modular content management system, with an active development community of its own. It provides a user management system and web 2.0 functionality such as user profiles, individual blogs and forums. The site was specialized with a range of modules to provide, for instance, twitter-like activity awareness, picture sharing and group management facilities to allow ad hoc teams to be constructed from among the membership as a whole for specific purposes (such as working on a specific response problem). It also includes mechanisms that establishing relationships to the virtual space, allowing users to associate their virtual personae with their web profiles, and links to allow users to “teleport” into relevant locations the virtual world. This site has been augmented by a wiki (powered by the popular open source MediaWiki software), to provide facilities for co-authoring text documents (a facility felt to be lacking at the time in Drupal). This wiki feature has itself been supplemented with experimental facilities for authoring and revising formalized standard operating procedures (Wickler and Potter, 2010): extensions to the wiki tag-set allow the imposition of meta-information (objectives, subtasks) on textual descriptions of the procedure; this meta-information facilitates subsequent searching and cross-referencing, and allows the execution of the procedure to be managed by external task-flow tools.

Figure 2. [openvce.net](#) web portal home page.

The deployment and administration of this web portal requires appropriate hosting hardware and a certain amount of expertise to manage the site and its users. This approach also allows for additional functionality to be made accessible to the community by embedding appropriate tools within site pages. These tools can be generic community tools or introduced for specific tasks.

Virtual Space for Intelligent Interaction: the I-Room

In addition to its social and entertainment uses, as argued above virtual worlds technology has the potential to enrich more serious forms of remote collaboration. We have developed these ideas into the concept of the *I-Room* (Tate et al., 2010). Put simply, an I-Room is an environment designed for intelligent interaction. It can provide support for formal business meetings, tutorials, project meetings, discussion groups and ad-hoc interactions. The I-Room can be used to organize and present pre-existing information as well as displaying real-time information feeds from other systems such as sensor networks and web services. It can also be used to communicate with participants, facilitate interactions, and record and action the decisions taken during the collaboration.

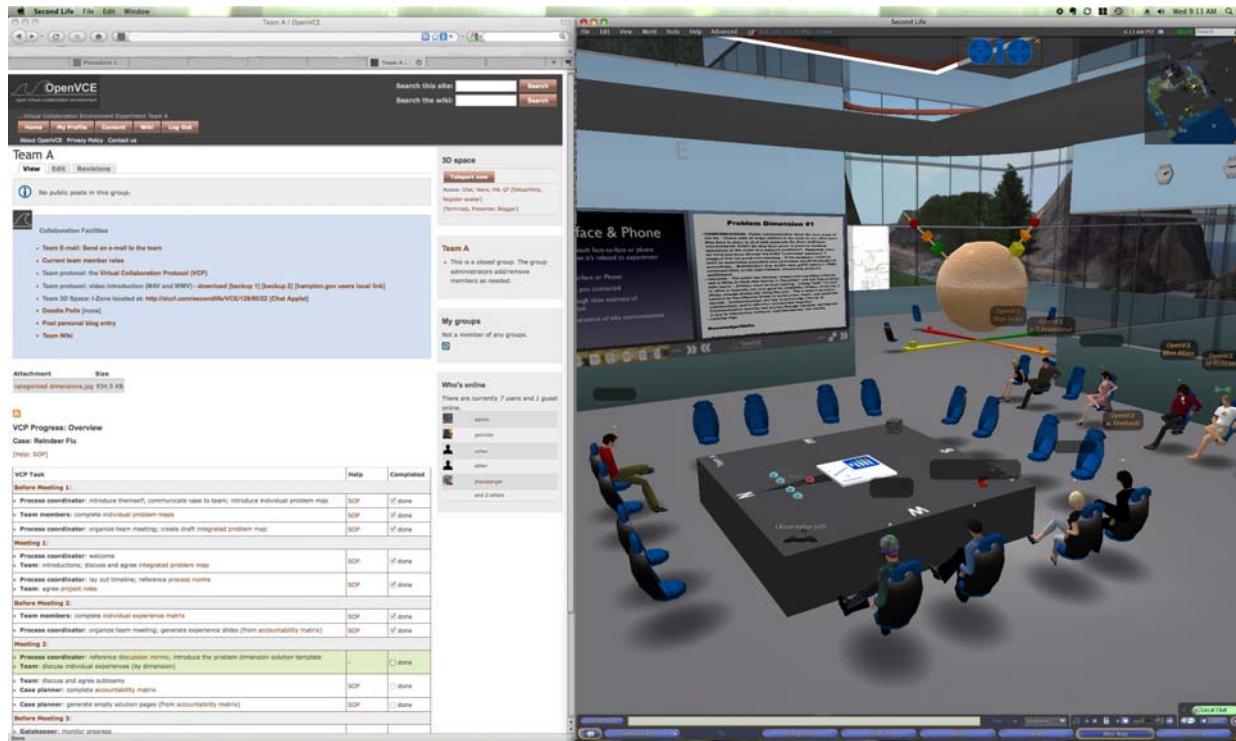


Figure 3. VCE web portal showing protocol support facilities, alongside an I-Room virtual space.

In practice, Second Life® and OpenSim environments have been used to realize I-Rooms (Figure 3 shows an I-Room alongside a browser onto the web portal, typical of how a user's screen might be laid out while using the VCE). Using the I-Room concept within virtual worlds gives a collaboration an intuitive grounding in a persistent space in which representations of the participants (their "avatars") appear and the artifacts and resources surrounding the collaboration can be granted a surrogate reality. Although for the uninitiated the virtual space can initially be disorienting and video game-like, in our experience users quickly feel comfortable in the space once any technical issues are ironed out (as is the case for other video-conferencing systems, these issues are usually related to audio difficulties or firewalls). Through an avatar a user can see the avatars of other users of the space, and communicate with those in earshot using spatialized voice (communication is also possible using general text chat and instant messaging). This audio-visual positioning in 3D space provides a compelling sense of shared presence with any other users currently in the same space; however, unlike video-conferencing, this medium lacks reinforcing cues such as eye-contact (along with all other forms of gestural communication) to confirm a speaker has the audience's attention or even that the members of the audience are actually 'in attendance' at their computers. Another difficulty, at least in the case of the chosen virtual platforms, is the mutability of a user's avatar – all aspects of its appearance, even its gender, can be changed on a whim – could lead to doubt about just whose presence one is sharing; and although each avatar has its name floating above its head, since permitted names are tightly controlled to ensure uniqueness this is only of limited value until a sure association with a human user is made. The VCE includes certain technical mechanisms, such as the provision of virtual name-tags, to assist in this aspect. These characteristics of the virtual worlds threaten to undermine social structures such as authority and trust that are

grounded in identity. (On the other hand, they could come to represent advantages of the virtual space, as visual prejudices must be put to one side.)

In addition to its use as a distributed access meeting space, the I-Room can be used to deliver intelligent systems and tool support for meetings and collaborative activities. In particular, the I-Room is designed to draw on I-X technology (Tate, 2000) which provides intelligent and intelligible (to human participants) task support, process management, collaborative tools and planning aids to participants. This technology encourages collaborators to share information about the processes or products they are working on through a common conceptual model called <I-N-C-A> (Tate, 2003), which describes a task in terms of issues to be addressed, nodes (activities) to be included, constraints to be respected, and annotations on these elements, and which is based on classic representations from AI planning, specifically hierarchical task networks (Ghallab *et al.*, 2004). This framework allows access to automated capabilities or agents in a coherent way, providing participants in I-Room meetings with, for instance, access to knowledge-base content and natural language generation technology.

Virtual Collaboration Protocol

It is one thing to provide an appropriate environment for interaction; it is quite another to expect people to use it straight away in the most effective manner, especially when one considers the potential novelty of many of the technologies involved. Furthermore, the success of collaborations is often determined to a great extent by the experience of those involved and their collective ability to organize their efforts. Accordingly, so as to provide some structure for collaborations, it has been necessary to consider the use of “virtual collaboration protocols”, intended to guide distributed collaborative activities across the diverse tools and organizations typically involved in crisis response. An initial protocol was developed (see <http://openvce.net/vce-protocol>) by Dr. Rob Cross (University of Virginia) that is intended to guide the behaviour of a team comprised of WoSCR members convened in order to provide expert advice to an external agency; it is expected that the request would be of a complexity that demands alternating virtual meetings and periods of diachronic effort from the team members. The protocol is influenced by Tuckman’s forming-storming-norming-performing collaboration model and by how individuals communicate and collaborate through social networks (Cross and Parker, 2004). One particular challenge that the protocol has to accommodate is coordinating efforts among a team without an initially designated leader, which is the case in many large-scale crisis efforts with multiple organizations. Early stages, which might be curtailed or omitted in subsequent collaborations, aim to establish familiarity with the process, awareness of the characters and abilities of the participants and foster the sense of ‘group presence’. Managerial roles are assigned, distributing responsibilities and authorities among the collaborators, before the team progresses through a series of different tasks that decompose the problem and then compose a solution.

To accompany this protocol tools based on the <I-N-C-A> framework have been developed and made accessible through the web portal to help track the status of the collaboration, manage roles, communicate with team members, and enter and share information. Furthermore, a number of standard operating procedures have been written using the Wiki to further decompose the subtasks detailed in the protocol in terms of the specific shared technologies that might be used to complete them (Wickler and Potter, 2010).

Integartion of the Three Technologies

In the description above, the three technologies are described as independent components. However, significant effort was spent to integrate these technologies to facilitate a coherent user experience. The central component around which this integration was achieved is the virtual collaboration protocol. The Wiki with its extension for encoding Standard Operating Procedures was used to make the protocol available in a convenient hyperlinked form to users of the VCE. This representation was also used to provide a “to-do” list in the Drupal portal that was visible to all authorized team members, showing current progress towards their goals (this “to-do” list can be seen in the browser window on the left of Figure 3). In addition to this, further assistance was made available through the portal for managing team membership, for the assignment of roles to team members, and for automatically generating templates for the collection of the information required from team members during the different phases of the protocol. Where appropriate, the contents of these completed templates were then used to generate collated summaries of the information gathered, and to provide ‘presentation slides’ that could be accessed and displayed on ‘screens’ in the I-Room to provide the basis for discussions during subsequent synchronous meetings of the team. Additional tools provided means of exploring databases of experts where it was recognized that the team lacked

certain vital expertise (a critical appraisal of the overall competence of the team with respect to the current task being itself part of the protocol). Neither the virtual spaces nor the collaboration protocol assume a specific crisis ontology (Bénaben *et al.*, 2008).

EXPERIMENTS

The VCE attempts to facilitate distributed collaboration by integrating asynchronous collaboration through web 2.0 technologies and synchronous collaboration through I-Rooms and virtual environments. Two experiments were conducted in 2010 to examine the impact the VCE had on crisis planning and collaboration when compared to traditional means of distributed collaboration among crisis response organizations and individuals. Results and conclusions from the second and more comprehensive of the two experiments will be discussed further.

The VCE experiment introduced a biological agent outbreak scenario to two teams comprising crisis expert volunteers distributed across the U.S., U.K., Canada and Italy. The traditional group (control condition) used technology and means that would normally be used for distributed collaboration across these types of organizations (government, industry, non-government, military, and academia) during a crisis, including email for asynchronous and telephone and teleconferencing for synchronous collaboration. The virtual group (experimental condition) used the full capability of the VCE as described in this paper. The traditional group consisted of 7 participants and the virtual group had 10 participants; each group had what was considered equal expertise in crisis response and biological outbreaks; and no members of either group had any prior experience of working together. Each group was given the same scenario and asked to generate a crisis response plan over four days.

For the virtual group, this meant following the virtual collaboration protocol, which guided team interactions through a series of semi-structured steps to identify key crisis areas, division of labor and roles for planning activities, and identify solutions to address the various elements of the crisis. The protocol guided and supported member activities for both asynchronous and synchronous interactions. The members of the traditional group, on the other hand, were free to organize their activities over the four days in whatever way they thought fit. As such, their success would depend on their existing abilities to coordinate and collaborate.

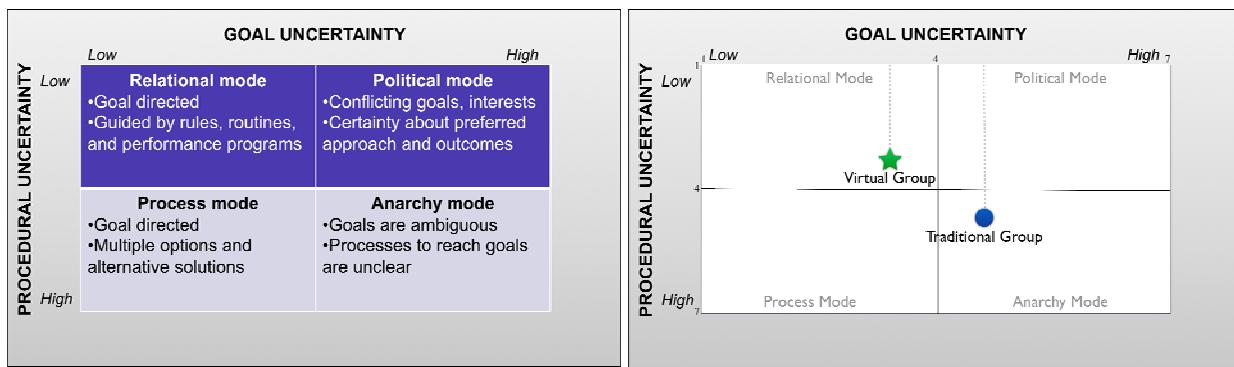


Figure 4. Goal and procedural uncertainty results from the virtual and traditional groups showing differences in uncertainty and the mode each group was interacting within.

In the event, both groups presented plausible solution plans as the outcome of their collaborations. However, initial semantic analysis results of the final plans showed the virtual group's final plan addressed more crisis response topic areas and addressed them in greater depth compared to the traditional group's final plan (Hansberger, 2010). In order to better understand these differences in the final plan, we examined some of the components of collaboration. Among one of the measurements taken each experiment day was a measure of uncertainty for each participant. Uncertainty was evaluated along two dimensions, namely *goal* and *procedural* uncertainty. Goal uncertainty is defined as the level of ambiguity a person has about the goals or objectives in their current situation or task. Procedural uncertainty, on the other hand, is how much ambiguity is associated with the steps or procedures necessary to accomplish the defined goals. Two seven-point Likert scale items measured each uncertainty dimension, which were averaged together. Choo (2005) has defined these uncertainty dimensions in terms of their

interactions with each other. The amount of goal and procedural uncertainty possessed by an individual and group will dictate the mode (see Figure 4, left) of interactions and ultimately the success of the group.

Placing the results for goal and procedural uncertainty along the uncertainty dimensions presents a clear picture of how much uncertainty was involved for each group (Figure 4, right). The traditional group finds themselves interacting in the “anarchy mode” where there is ambiguity with both goals and procedures. Group and individual feedback after the experiment confirms this finding. There was considerable effort needed by this group to establish a common ground and understanding within the group before they could engage in any planning efforts. This is also indicative of collaboration efforts among many different organizations, involving people with different backgrounds and expertise, particularly when they have not worked together before. The virtual group using the VCE and collaboration protocol fared much better and found themselves working within the “relational mode” where goals and procedures are clear and understood. The overall difference between the two groups was statistically examined using repeated measures analysis of variance (ANOVA) and there was a significant difference between the two groups as suggested in Figure 4 ($F = 10.31, p < .01$). The virtual group had less goal and procedural uncertainty as they collaborated with their colleagues, which can result in increased efficiency and performance. These findings provide some evidence of the positive influence that can be gained using integrated technologies to support both asynchronous and synchronous collaboration over space and time.

CONCLUSION

The Virtual Collaboration Environment has been developed as a means to support the activities of distributed communities, specifically – but not exclusively – the activities of the WoSCR community. It is intended to supplement existing web 2.0 with virtual spaces that provide a means for the simultaneous presence that is a prerequisite for certain aspects of collaborative activity. Protocols and other tools are provided to help with the use of this environment.

The efforts described in this paper have been driven by the idea that these new technologies offer new possibilities for task-directed distributed collaboration, and the desire to experiment with these. The cognitive work analysis and the results of the experiments provide a certain amount of justification for their use, but further work is needed to put the technologies and the ways in which they are used on a firm theoretical footing. This need is both confirmed by and made more difficult by the rate at which web 2.0 and virtual technologies are developing, and are subject to the vagaries of fashion and popularity. Attempts to keep abreast of these developments have required a great deal of technical experimentation and back-tracking, as we have watched new technologies emerge and supersede others, some of great potential. This has resulted in a certain ad hoc flavour to some of our work. However, underpinning all these efforts is the awareness that these technologies offer the emergent and often incidental property of allowing their users to assert their presence as participants in distributed communities; and also of the vital role that presence plays in any serious collaborative activity.

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